PERENCO REP

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Technical note for onshore wells abandonment

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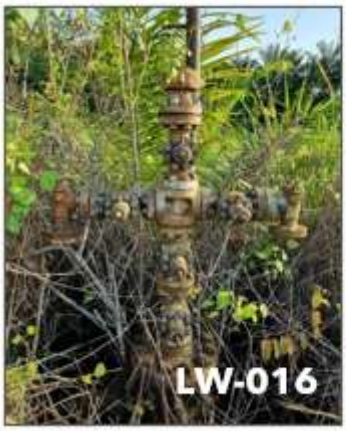
June 2023



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1. Terms and definitions

1.1 Definition of decommissioning

Decommissioning is the process of ending oil and gas operations and returning the site of exploitation to its pre-lease condition.

Oil and Gas decommissioning is the process of plugging and abandoning wells then removing or repurposing infrastructures at the end of its useful life. All the measures to decommission disused installations will be described in methods to undertake the work once the economic cut-off of the assets is reached.

Prior to decommissioning, it is required to establish relevant methodologies, programs, schedules, and cost estimates to be validated by the National Authorities who will comment and validate the proposals set out in the programs.

1.2 Why doing anticipated decommissioning activities?

Usually, the decommissioning process takes place at the very last end of a lease when no more recoverable potential of hydrocarbons is met. However, wait for the very last moment could put a risk in the operations. It is crucial to ensure that the whole process, from late-life asset management through to final decommissioning, is as effective and efficient as possible. Effective decommissioning – and, before that, efficient late-life asset management and operations – are fundamental to maximizing the economic potential of the region.

1.3 Glossary

- **Artificial reef:** It refers to an underwater platform structure which is abandoned and let onto the seabed. Artificial reefs also contribute to promote local marine life.
- **Completion:** Tubing and downhole equipment required to produce the well, at the end of drilling operations.
- **Conductor pipe (CP):** Large diameter pipe set in the ground or seabed before any drilling operation. It provides the initial structural foundation for a well.
- **Flowline:** Pipeline connected between the wellhead or X-mas tree and the process station to transport the production fluid.
- **Flush:** Operation which consists in injecting water into a pipeline to remove deposits and clean it.
- **Inflatable plug:** Plug inflated in a well to perform zonal isolation. Cement is pumped thereafter to complete isolation.
- **Jacket:** platform built on steel legs anchored onto the seabed, supporting a deck (topside) with drilling rig, production facilities and living quarters.
- **Jack-up:** Platform or rig that can be jacked up above the sea using legs that can be lowered.

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- **Milling:** In our case, milling operation is required if a packer cannot be retrieved. This packer will be drilled out to surface with a special tool.
- **OGA:** Oil & Gas Authority (now **NSTA** – North Sea Transition Authority).
- **Overpull:** While pulling a completion out of hole, restrictions or irregularity in the well can lead to excessive tension on string.
- **Packer:** Completion equipment used to seal well annulus from produced reservoir.
- **Pipeline:** Steel or plastic tubes used to transport oil, water, or natural gas.
- **Platform:** Offshore structure with facilities to drill wells, extract and process oil and natural gas, or to temporarily store production until it is brought to shore for further treatment.
- **Process line:** It refers to piping, electrical and instrumentation network within a process station or platform.
- **Processing equipment:** It refers to production vessels necessary to process oil, gas, and water to bring them at transport or sales specifications.
- **Remedial cement job:** In case of bad cement job, a second cementing operation is performed.
- **Rigless:** Abandonment operation performed on a platform without using a rig or a workover unit.
- **Topside:** It refers to the upper modules of a platform, above the sea level, on which production facilities and living quarter are installed.
- **Workover unit:** mobile rig used to perform one or more remedial operations on an oil or gas well. Workover unit can be an hydraulic systems, cable unit for example.
- **X-mas tree:** An assembly of valves, spools, pressure gauges and chokes fitted to the wellhead of a completed well to control production

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2. The Decommissioning Process – Overview

This section provides an overview of the decommissioning process from planning to field operations for well, pipeline and platform abandonment.

2.1 Pre-job Activities

Before any physical decommissioning work can commence, several pre-job activities must be completed. The pre-job components of a decommissioning program consist of the following activities:

- Decommissioning Planning
- Decommissioning Engineering
- Operations execution
- Site clearance
- Authorities approval

2.1.1 Decommissioning Planning

Decommissioning planning includes gathering and reviewing platform, installation, pipeline and well information, preparing a decommissioning estimate (in terms of scope of work, scheduling, cost evaluation), and performing an inspection of the platform or the installation onshore. This is the initial phase of the decommissioning project. All information available for each facility to be decommissioned (structural drawings, installation records, process flow diagrams, pipeline maps, etc.) is first gathered and reviewed. Based on the information retrieved, various removal methods (i.e., Complete Removal, Partial Removal, and Remote Reefing) may be evaluated.

An Approval for Expenditure (AFE) cost estimate for each platform is developed and submitted to the platform owner for approval. In cases where multiple platforms are to be decommissioned, this AFE will consider grouping the platforms to realize any economies of scale. Concurrently, a detailed project schedule is developed.

After the AFE is approved, installations are inspected to appraise the overall condition. For offshore, a specific inspection is down for its condition, drilling and production deck dimensions, equipment location, pad eyes, risers, etc. A detailed inspection punch list is submitted to and agreed upon with the platform owner prior to these inspections.

2.1.2 Decommissioning Engineering

Detailed engineering is carried out to determine the specific procedures, vessels, equipment, and manpower that may be used in the decommissioning process. The analyses

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include the determination of the weights of individually removed pieces, crane and vessel capacities, and the structural stability of the platform at all stages of the dismantling process.

A major consideration is the ability to safely remove platform components and sections. Deck and jacket actual weights, the center of gravity, and the center of buoyancy are needed for the platforms and major subsea equipment. Lift analyses are developed by structural engineers; all calculations are reviewed and approved by the project manager.

2.2 Well Plugging and Abandonment

Production wells that can no longer be used must be plugged to prevent the oil and gas reservoir fluids from migrating up hole over time and possibly contaminating other formations, freshwater aquifers, or the marine environment. A well is plugged by setting mechanical or cement plugs in the wellbore at specific depths and intervals to prevent fluid flow. The main rigless plugging process usually requires a spread containing the following: pump, cement blender, a combination wireline/ electric line unit, mud tank and commonly used materials such as cement, bridge plugs, and cutting equipment to conduct the operation.

2.3 Pipeline Decommissioning

Pipelines may be either removed or, with a waiver, abandoned in place. Prior to removal, pipelines must be pigged and flushed with water. Pipelines abandoned in place must be flushed, filled with seawater, cut, and plugged with the ends buried at least 0.6m below the surface for offshore lines. Pipelines that are abandoned in place must not pose hazards to navigation hazards, commercial fishing, or other activities.

2.4 Platform Decommissioning

The platform removal process is inclusive of the following operations: platform cleaning, conductor removal, deck and equipment removal, jacket or hull removal and disposal. The description of each operation is described below.

2.4.1 Platform Preparation and Cleaning

Platform preparation includes the procedures associated with shutting down and preparing the facility for removal. Topside inspections and underwater inspections are generally conducted to determine the condition of the structure and to identify any problems for removal. Inspections underwater can be carried out by divers or ROV depending of availability and/or water depth (to avoid expensive saturation diving in water depth greater than 50m. After the inspections have been completed, a crew prepares the structure for decommissioning after the wells have been permanently plugged and abandoned and the pipelines have been abandoned.

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On the surface (topside of the platforms), the work includes the flushing/cleaning and degassing/purging of tanks, processing equipment and piping, disposal of residual hydrocarbons, removal of platform equipment, cutting of piping and cables between deck modules, separation of modules into individual units, installation of pad eyes for deck module lifting, removal of obstructions to lifting, and structural reinforcement. Topside preparation also includes severing connections between the deck and jacket and verifying that all pipelines have had a section of pipe removed between the deck and jacket.

The key factors affecting the cost of platform preparation include structure size and complexity, topsides equipment (especially the amount of processing equipment), and age of the facility. The costs can vary widely depending on the type of facility, removal procedures, and transportation and disposal options.

2.4.2 Conductor Severing and Removal

The conductors can be removed prior to the HLV arrival or removed during platform decommissioning operations with the HLV. All conductors are severed and completely removed at least 0.5m below the mudline. The conductors are severed by one of the following methods:

- Explosives
- Abrasive Cutting
- Mechanical Cutting
- Diamond Wire Cutting

One or a combination of the following are used to pull the conductors:

- Casing jacks
- Drilling rig if present
- Platform crane
- Crane on an HLV

Regardless of the lifting device, the removal sequence is the same. The conductor is pulled upward until a sufficient section is exposed. The conductor is cut using external mechanical cutters or possibly the threaded connections are unscrewed. The cut section is then removed by the drilling rig or platform crane and placed on a workboat, cargo barge or on the deck away from the work area. This procedure (pull, cut and remove) is repeated until the entire conductor is removed. The jacks onboard may not be able to pull the combined weight if the conductor is grouted. In this case, a rig or crane is used until the jacks can pull unti enough tension is provided to lift the weight of the conductor by themselves.

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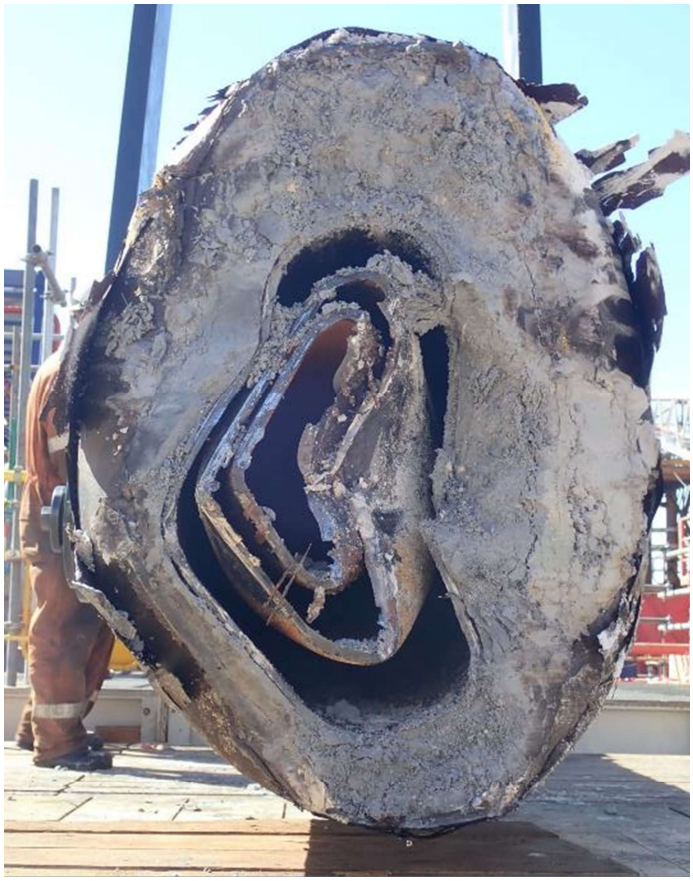

Figure 1: conductor cut and recovered at surface.

2.4.3 Removing Deck and Modules

Topsides removal follows the installation process in reverse sequence. Some deck removals will require that modules are removed and placed on a cargo barge. The module is secured by welding pieces of steel pipe (or plate) from the module to the deck of the cargo barge. If the deck is planned to be lifted in multiple sections, e.g., removing two 4-legged section from an 8-legged deck, the deck is severed into two section, the connection between the deck and jacket are severed and each section is lifted and placed on a cargo barge and the legs are secured to the deck by welding.

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Figure 2: Amethyst C1D topside skidded inside ERDA jack-up barge (courtesy of Petrodec BV)

One of the emerging decommissioning processes will be deck removal by the float over method. This has not been a method of installation or removal because HLVs of sufficient size have not existed until recently. A specially designed vessel was used that can be partially submerged by ballasting and raised by ballasting.

2.4.4 Jacket Removal

2.4.4.1 Fixed structures, Complete Removal

Jacket removal involves separating the structure from its foundation and transporting it in whole or in pieces to a scrap yard where it is cut up and recycled.

Most jackets are separated from their foundations with explosives although non-explosive removal techniques are becoming more common.

Explosives are placed in the main piles and skirt piles at least 0.5 m below the mudline. If the mud plug inside the piles is not deep enough to allow the explosive charge to be placed at the required depth, the mud plug is jet/air lifted.

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Figure 3: Tyne platform jacket complete removal (courtesy of Perenco UK)

2.4.4.2 Fixed Structures, Partial Removal

This scenario involves removing only the top section of the jacket. The jacket's legs are severed as in complete removal, except that the cuts are made at the top of the portion of the jacket that will remain in place. The remaining structure must not become a marine obstruction. This removed section of the jacket will either be transported to shore for disposal or reefed in place or at another approved reef location. If approved by the local authorities the remaining structure can be left in situ as artificial reef.

2.4.4.3 Fixed Structures, Reefing

After the topsides are removed the jacket is severed as in the complete removal method. If the jacket is to be transported to an alternate reef site, the jacket is then made buoyant as in the complete removal method.

Reefing may involve complete or partial removal of the jackets. Structures may be reefed in place or reefed at another approved location. The jackets are severed below the mudline

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(for complete removal) or severed at some partial depth (for partial removal) as described above.

Figure 4: Marine growth and fish habitats development on steel jacket structure in Gabon

If the jacket is reefed at an alternate approved reef site, the jacket is transported to the site by the HLV or by pull tugs. At the reef site, the jacket is lowered by ballasting the piles and the base is set on the sea floor. The jacket is pulled over and left on its side at the reef location with a marker buoy placed on location above the jacket.

2.4.4.4 Floating Structures

Floating structures are moored to piles installed in the seabed with steel pipe, steel or polymer cables, steel chains, or a combination thereof. The mooring lines are released from the hull and the hull is towed to a shore disposal facility. The mooring lines are severed from the anchor piles and removed.

2.5 Disposal

The cargo barge transports the deck and modules to a scrap yard. The modules may be lifted with cranes or skidded off the barge to the yard. Once the modules have been removed from the barge, the deck is skidded off the barge to the yard. All of the structural components and modules are cut into small pieces and disposed of as scrap unless the deck will be reused. The production equipment is salvaged for reuse whenever possible.

2.6 Site Clearance and Verification

Following removal, the platform site, and any location where the jacket is cut will be cleared of debris and verified that it has been cleared. The site is cleared using trawlers dragging nets across the bottom in a recorded grid pattern of specified dimensions.

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2.7 Post-job Activities

Each decommissioning phase requires a report be submitted to the regulator. These reports are submitted to the platform owner for review and approval. Once approved, the project management group submits the reports to the appropriate regulator office.

2.8 Authorities approval of decommissioning activities

At the end of the decommissioning operations, relevant authorities should validate the way the installations/wells were decommissioned to justify that all operations were performed properly. It is therefore mandatory to get a post job report validated by both parties (State and company).

This post decommissioning certificate related to relinquishment must include an abandonment of liabilities for Perenco.

All the legal responsibilities following decommissioning (ownership of installations, production license, liabilities, etc.) shall be clearly defined.

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3. Wells decommissioning techniques and guidelines

This section covers the methodology used to plug and abandon wells. The following technical procedures will have to be discussed and approved before each abandon operation, depending on each well condition.

3.1 Wells methodology

A good reminder for wells plugging and abandonment has been published by EHS:

EHS Guidelines for Onshore O&G development:

"Wells should be abandoned in a stable and safe condition. The hole should be sealed to the ground surface with cement plugs and any known hydrocarbon zones should be isolated to prevent fluid migration. Aquifers should also be isolated. If the land is used for agriculture, the surface casing should be cut and capped below plow depth."

The type of abandonment unit used for such operation will mainly depend on unit capacity and expected well difficulties. Two types of units will be used, an onshore pulling unit and an onshore mini rig.

The choice of the type of workover unit to be used for well abandonment operations depends on various criterion. Depths, weights, abandonment procedure or specific capacities can be required depending on the well status and the downhole completion.

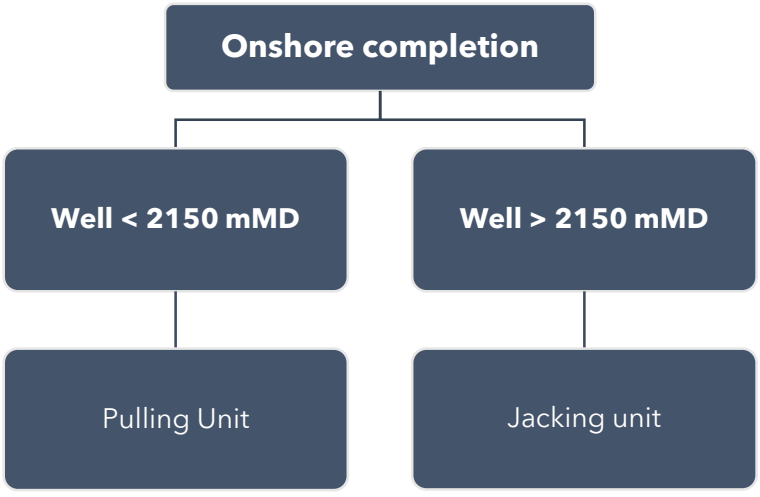

Figure 5: Onshore abandonment equipment distribution summary

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3.2 Well decommissioning guideline and regulations

The British regulator (OGA) has published several guidelines for the operators regarding well plugging and abandonment.

These guidelines have been prepared to support operators on the considerations that need to be taken during the phases of decommissioning a well. The intent of these guidelines is to provide the framework for the risk based decision-making process that should accompany nay well decommissioning activity.

Decommissioning of wells is concerned with the isolation of rock formations that have flow potential. An assessment of the flow potential of individual formations penetrated by the well is a key input to the design of well barriers.

Flow potential originates mostly from formations with permeability and a pressure differential with other formations or surface. Indications of flow potential are based on drilling records (gains/losses/gas levels), log evaluation (including from adjacent wells), well annuli pressures and subsurface modelling.

Formations may be grouped into zones of similar fluids and or pressures where inter-zonal isolation has been assessed as not required, or where the consequences of cross flow are deemed acceptable. Such a group of formations can be isolated by a common barrier or dual barrier if required.

3.3 Permanent barriers

3.3.1 Overview

The underlying principle on which all guidelines are based is the restoration of the cap rock.

The material, number, position, depth and placement method of barriers should be based on assessment of well conditions, formation fluids, pressures, formation strength, potential flow rates, sustainability of potential flow, environment impact.

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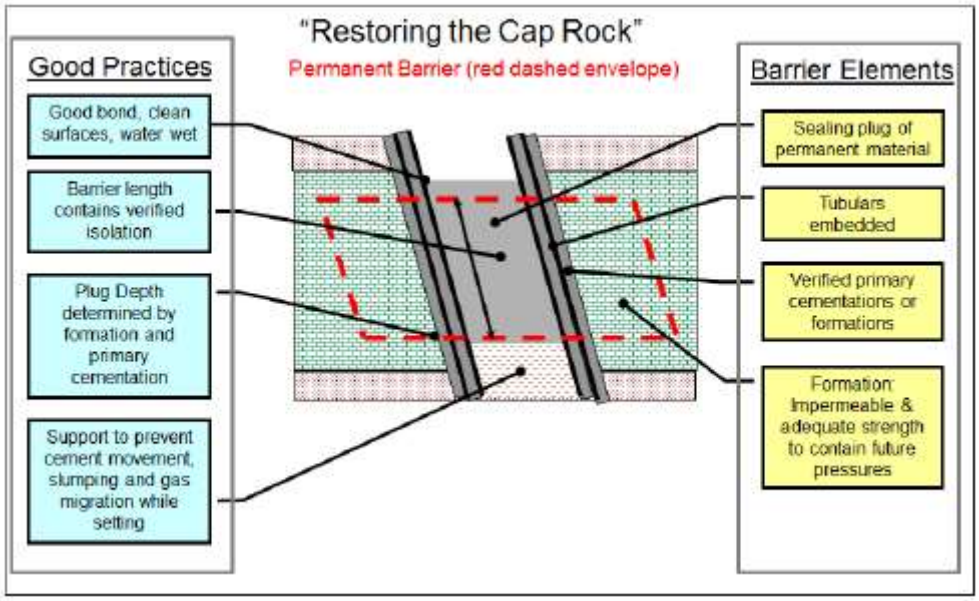

Figure 6: Permanent Decommissioning Barrier Schematic

3.3.2 Material requirement for permanent barriers

The main characteristics of placed barrier materials (not limited to cement) should be as follows:

- Impermeable – to prevent flow of fluids through the bulk material.
- Provide an interface seal – to prevent flow of fluids around the barrier; the material provides a seal along the interface with adjacent materials such as steel pipe or rock.
- Remain at the intended position and depth in the well.
- Long-term integrity – long-lasting isolation characteristics of the material, not deteriorating over time.
- Resistance to downhole fluids at foreseeable pressures and temperatures.
- Compatibility of barrier material with adjacent geology.

3.3.3 Number of permanent barriers

All penetrated zones with flow potential that have been identified as requiring isolation should be isolated from surface by a minimum of one permanent barrier, or two as appropriate. Where cross flow is deemed unacceptable, zones should be isolated from each other.

The actual number of barriers required should be determined by risk assessment and they may differ from the numbers below. When considering the number of barriers for water-bearing zones, a single barrier has been specified as a minimum. This approach should be risk assessed and operators should consider increasing this requirement based on, but not limited to, the following considerations:

- Differential pressure across the barrier
- Impact of single point failure

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- Robustness of barrier placement and verification

Generally,

- One permanent barrier from surface or seabed may be considered if a zone requiring isolation is water-bearing.
- Two permanent barriers from surface or seabed are recommended if a zone requiring isolation is hydrocarbon-bearing or water bearing and significantly over-pressured.

The two permanent barriers may be combined into a single large permanent barrier (combination barrier), provided it is as effective and reliable as the two barriers and is an appropriate method to achieve the objectives that two barriers would otherwise have provided.

Regarding the length requirements of permanent barriers, the followings should be considered.

3.3.4 Length requirement of permanent barriers

3.3.4.1 Cement

A permanent cement barrier should have:

- A cement column of typically a minimum 100 ft measured depth (MD) of good cement to constitute a permanent barrier whether inside or outside the casing.
- Typically, 100 ft MD of good cement above the zone with flow potential.
- The internal cement plug adjacent to the annular good cement over a cumulative distance of typically 100 ft MD of overlap.

When a combination barrier is chosen to replace two barriers, it should have:

- A cement column of typically a minimum 200 ft MD of good cement, which is considered to constitute such a permanent combination barrier.
- Typically, 200 ft MD of good cement above the zone with flow potential.
- The internal cement plug adjacent to the annular good cement over a cumulative distance of 200 ft MD of overlap.

A reduction in the lengths stated above should only be used if a rigorous risk assessment process has been followed. Thereby demonstrating that the risks associated with a barrier less than 100 / 200 ft are as low as is reasonably practicable (ALARP).

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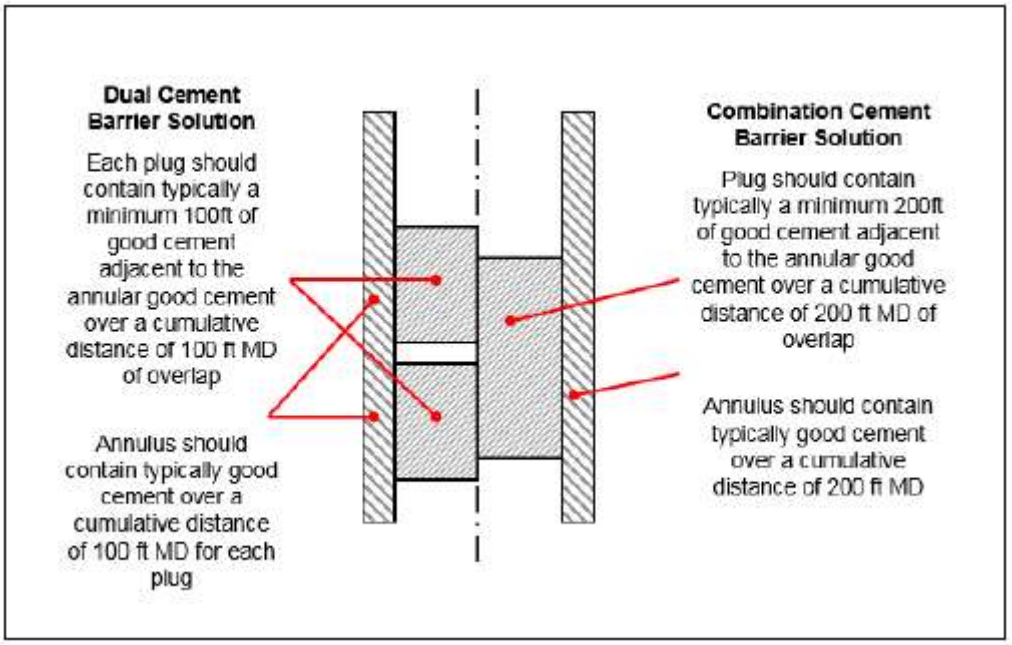

Figure 7: Comparison of length of dual combination cement barriers

3.3.4.2 Sealing formations

Certain formations (e.g. certain shales or certain salts) are known to move as a result of stress differences. These formations can close an annulus space where cement is absent or incomplete. Typically, such moving formations are a geological feature that is observed field-wide and is not an isolated well related feature. To be considered for use as a barrier, the formation should be impermeable and have adequate strength; these properties should be lasting at the prevailing conditions.

If it can be demonstrated that the cumulative length of the resulting seal of the formation against the casing is adequate to prevent flow of the present fluids at the maximum anticipated pressures, then such a seal is acceptable as a replacement for a good annulus cement bond.

The internal barrier material should be adjacent to the annular isolation providing sufficient cumulative length above the zone with flow potential.

3.3.5 Position Requirements of permanent barriers

The first barrier above the zone with flow potential is referred to as the primary barrier; the next barrier above the zone with flow potential, **where required**, is referred to as the secondary barrier.

A permanent barrier should:

- Be set above the zone with flow potential across a suitable cap rock.

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- Extend across the full cross section of the well and include all annuli. The environmental plug is not governed by this rule.
- Have formation fracture pressure at the base of the barrier in excess of the maximum anticipated pressure from the zone being isolated.

A suitable cap rock is impermeable, laterally continuous and has adequate strength and thickness to contain the maximum anticipated pressure from the zone being isolated.

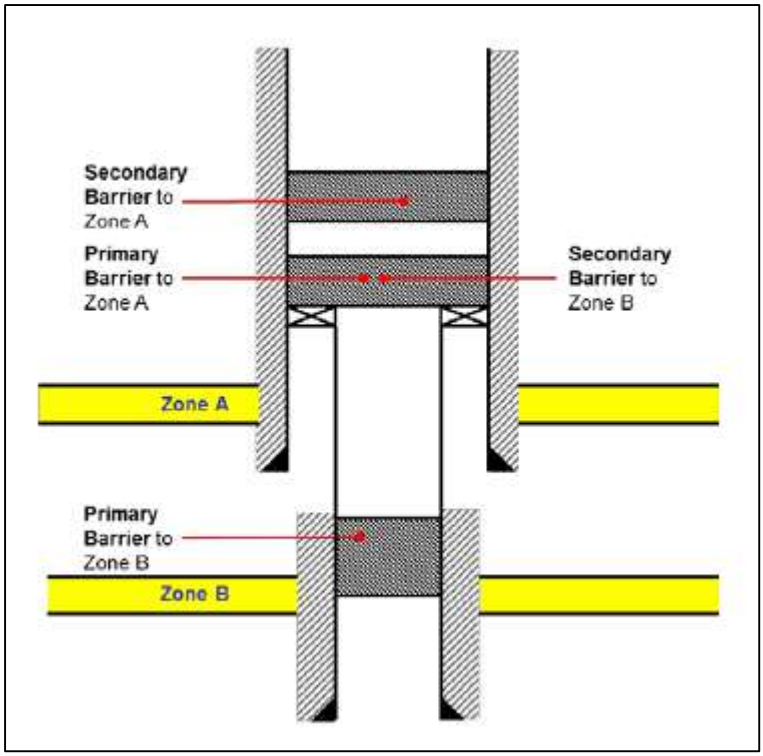

Figure 8: General requirements for well decommissioning

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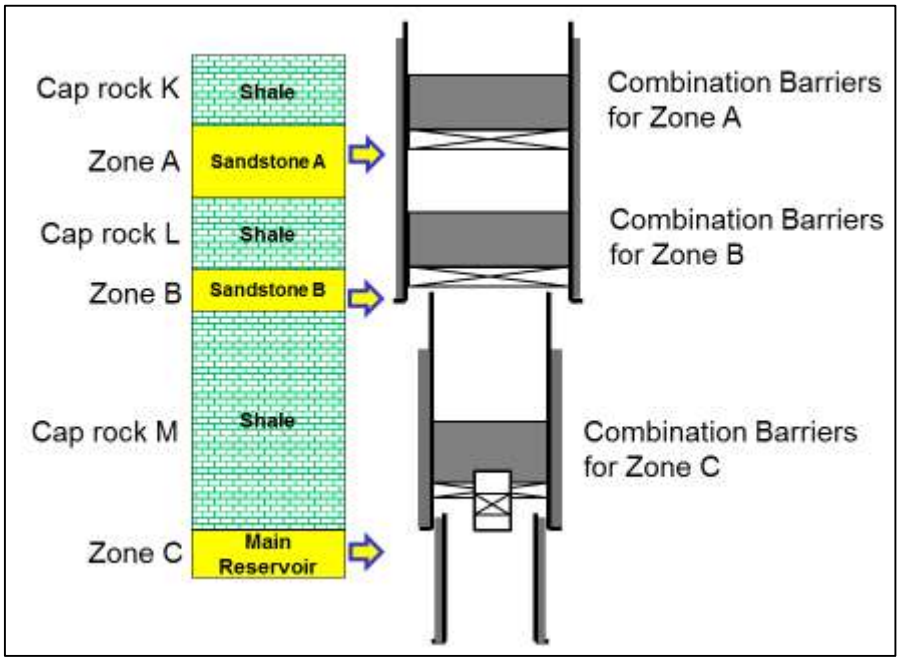

Figure 9: Barrier position is determined by the geological setting, i.e. permeable formations as source of inflow and cap rock

Two barriers are shown per zone with flow potential in the above figure (Figure 9). This will be the case if barriers cannot be shared, i.e. cap rock L is not capable of containing the maximum anticipated pressure from the main reservoir, or cap rock K is not capable to contain the pressure of sandstone B.

3.3.5.1 Open Hole

This section covers barrier position where the zone with flow potential is not behind the casing.

For open hole isolations, it is recommended to set a permanent barrier in cased hole (Figure 11) or to extend sufficiently into cased hole (Figure 10). The barrier across cased hole is to fully isolate the open hole and allow for a pressure test.

Zones with flow potential that belong to different pressure regimes should be separated by one permanent barrier unless crossflow is acceptable (see Figure 12).

Where the pressure from a zone with flow potential is anticipated to exceed the formation fracture pressure anywhere in the open hole, it should be isolated by two permanent barriers or a combination barrier (See Figure 13).

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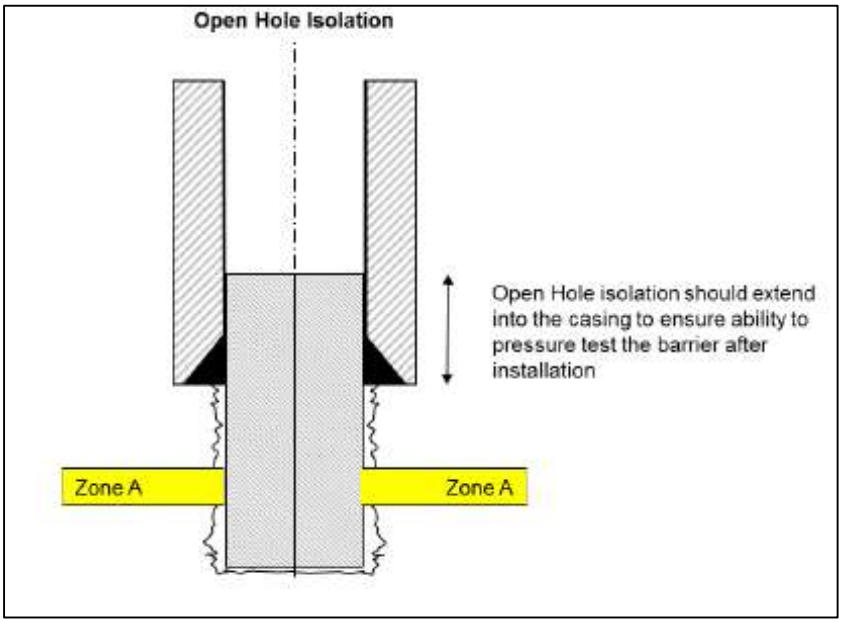

Figure 10: Example Open Hole permanent barriers (if the open hole strength would not allow pressure testing from above)

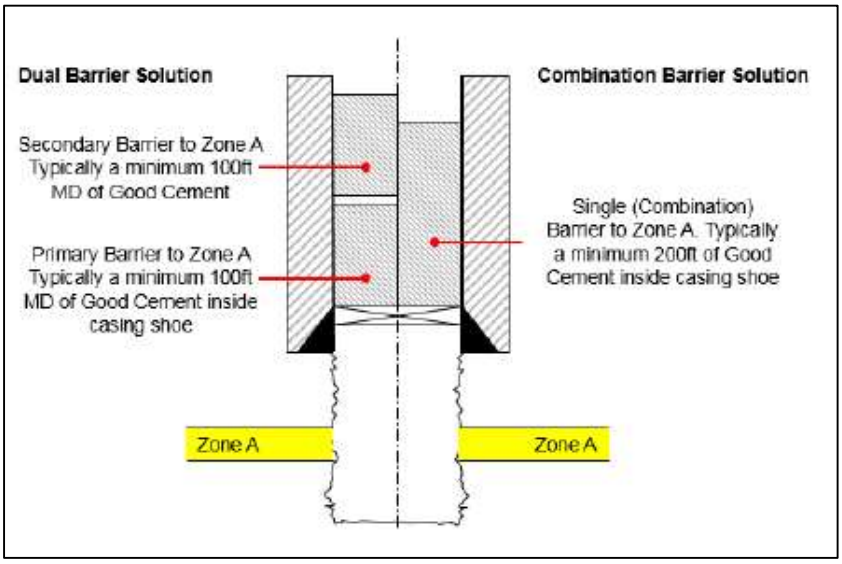

Figure 11: Example Open Hole permanent barriers (if open hole strength is sufficient for maximum pressure from zone A)

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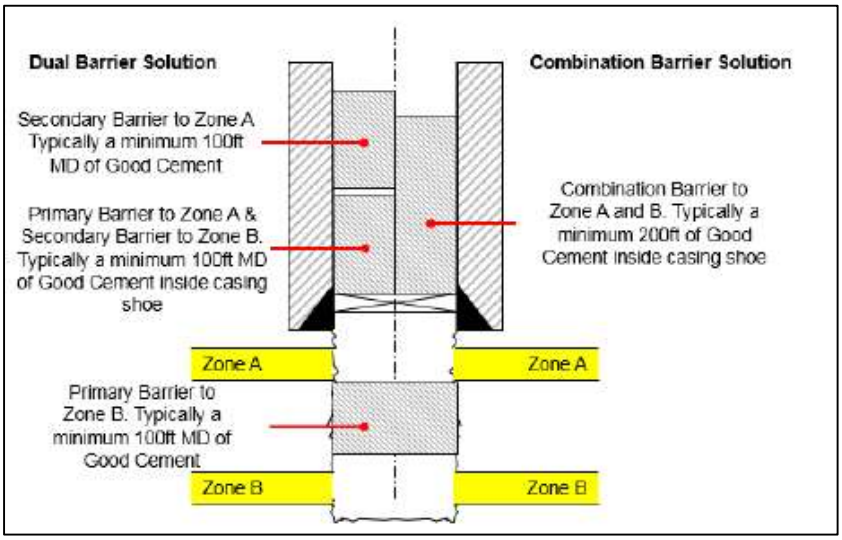

Figure 12: Example Open Hole permanent barriers if zone A requires isolating from zone B (if maximum anticipated pressure from zone B does not exceed the casing shoe fracture pressure, one permanent barrier between zone A and zone B is adequate)

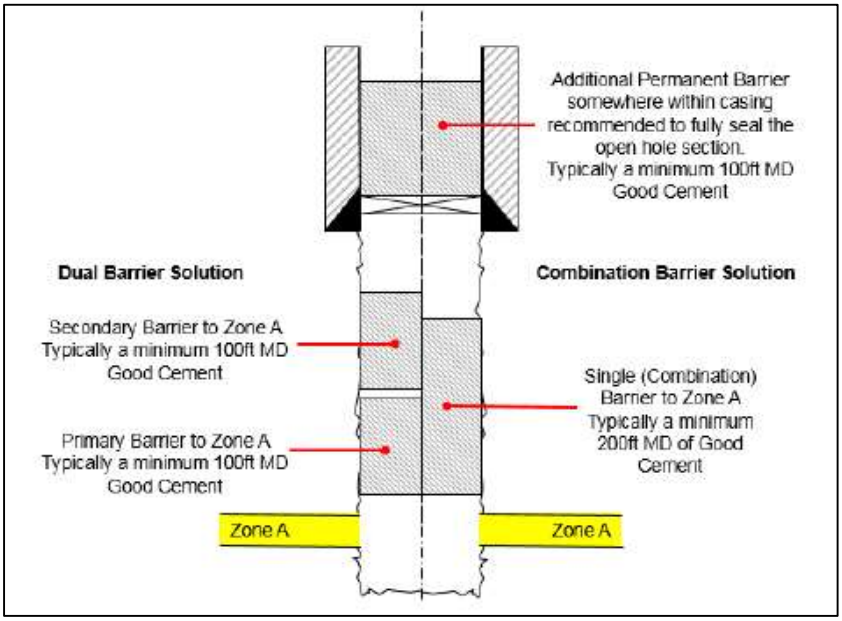

Figure 13: Example Open Hole permanent barriers (if maximum anticipated pressure exceeds the casing shoe fracture pressure)

3.3.5.2 Partial decommissioning for sidetracking and multilaterals

Where an open hole has been sidetracked and subsequently cased across the kick-off point without achieving a top of cement into the previous shoe (see Figure 14), a suitable barrier should be set above the sidetrack point.

If the kick-off plug is being used as a permanent barrier, then the remaining barrier, after kick-off, should conform to the minimum requirements of a permanent barrier (see also Figure 14).

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Isolation needs to be considered to ensure adequate well control in subsequent drilling operations. For deep sidetracks in the reservoir, isolation from the original wellbore, across the sidetrack point, may be required for reservoir management during production life.

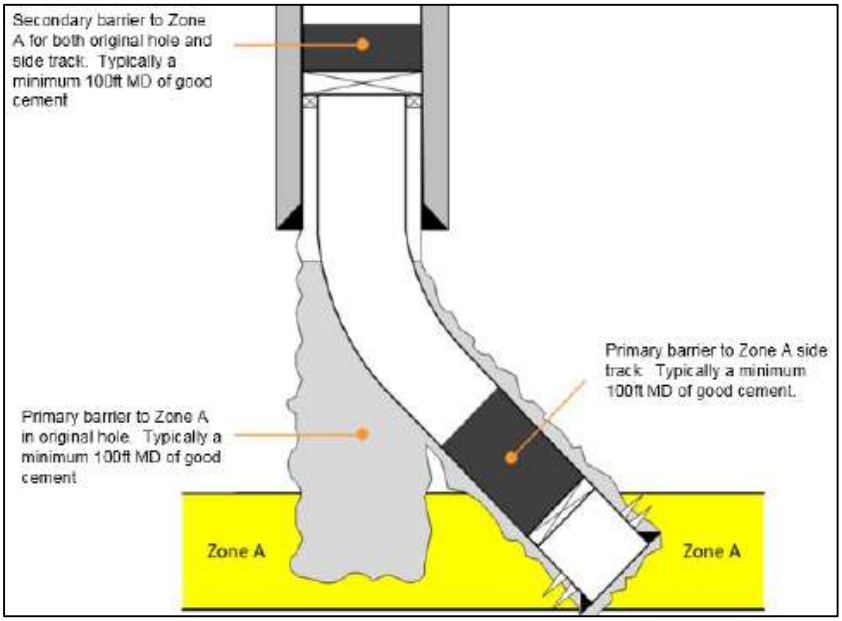

Figure 14: Example permanent barriers for side-tracking

3.3.5.3 Cased Hole

A full lateral barrier in cased hole consists of annulus isolation and overlapping internal casing isolation.

Cemented casing alone is not considered to constitute a permanent barrier to flow laterally into or out of the wellbore (refer to Figure 15).

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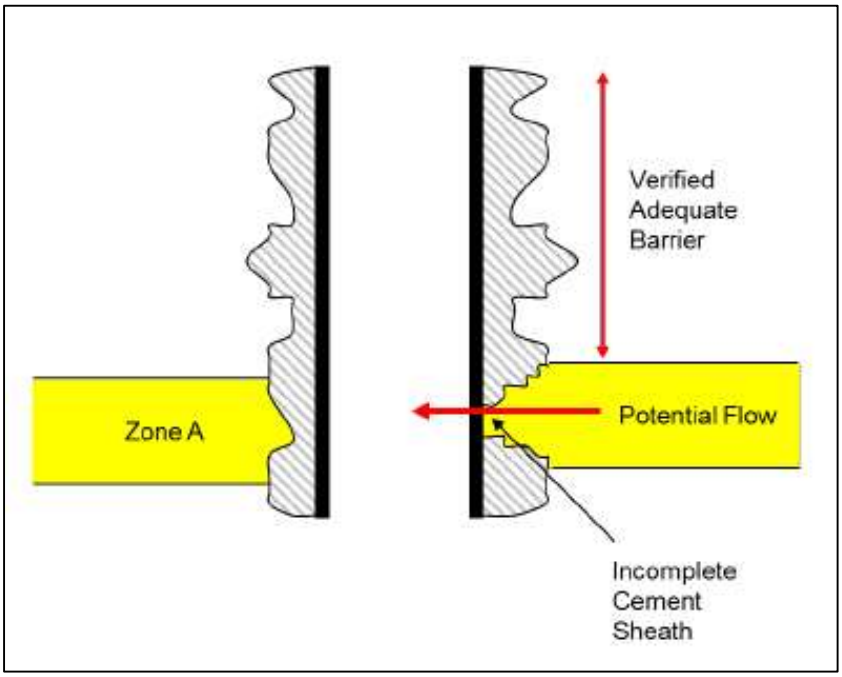

Figure 15: Casing alone is not a permanent barrier to lateral flow.

Similarly, to Figure 15, inside cased hole, a permanent barrier requires both a cement plug or equivalent inside the casing and overlapping good annular cement or equivalent as per Figure 16. In this example zones A & B have flow potential, and belong to different pressure regimes, so should be separated by one permanent barrier internally.

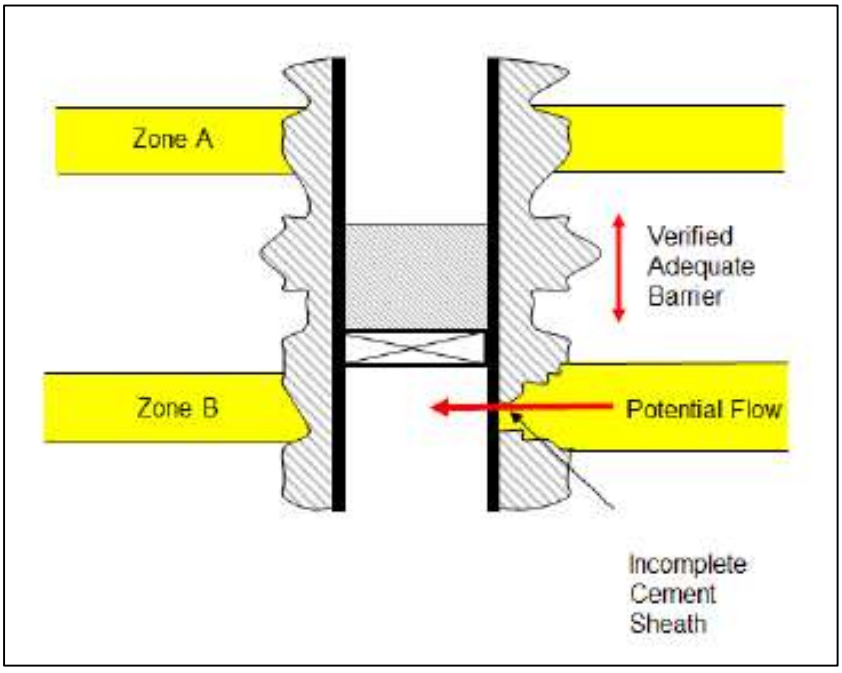

Figure 16: Different pressure regimes should be isolated internally by a minimum of one barrier. This will prevent cross flow due to an incomplete localized cement sheath and leak in casing.

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The barrier in Figure 16 is placed on a firm support to prevent slumping of the cement slurry down the well. Consideration should also be given to gas migrating upwards as the cement is thickening. These considerations are equally appropriate in open hole.

3.3.6 Placement of permanent barriers

The downhole placement technique of the barrier material is extremely important, especially in cases of through-tubing applications, high angle wells, HPHT etc.

To achieve the required barrier length, allowances will have to be made on volumes to cater for uncertainties during placement. It may be necessary to place up to 500 ft MD of cement to achieve 100 it of good cement. Similarly, it may be necessary to place up to 800 ft MD of cement to achieve 200 ft good cement. Optimization of barrier placement may allow reduction of length from the values noted above whilst considering some of following during engineering:

- Hole conditions
- Inclination
- Fluid density hierarchy
- Stinger geometry
- Verification method
- Offset experience.

Generally, the additional cost of placing more cement is far outweighed by the implications of a leaking barrier. However, circumstances may arise where it is impractical to place such a typically sized barrier.

3.3.6.1 Through tubing decommissioning

When well completion tubulars are left in hole and permanent barriers are installed through and around the tubulars, reliable methods, and procedures to install these barriers should be established. See Figure 17 as an example of Through-Tubing cased hole decommissioning.

Allowances should be made for:

- Cement slumping
- Channeling
- Lack of centralization
- Small radial clearances
- Tubing integrity
- Full annular coverage
- Contamination
- Tubing debris, such as wax and scale
- Cables and control lines

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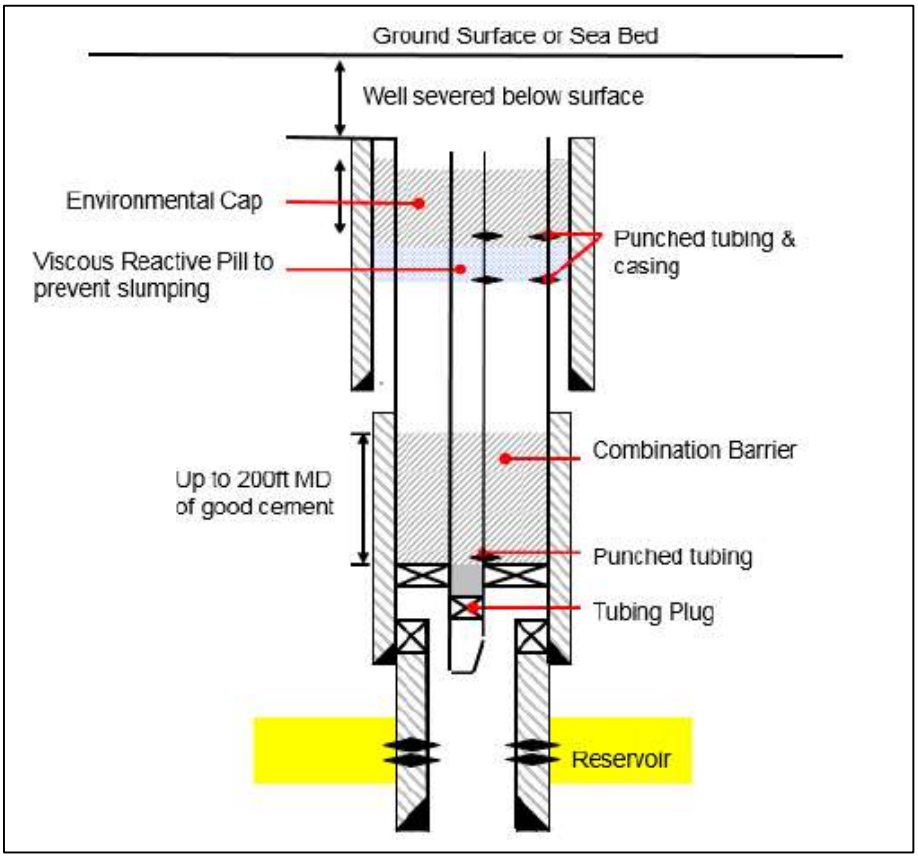

Figure 17: Example Through-Tubing cased hole decommissioning schematic

3.3.6.2 Penetrations Through Permanent Barriers

Provided the isolations outlined in these guidelines are achieved, cables and control lines can form part of permanent barriers. Assessment of potential leak paths and the plugging thereof should be conducted. A rigorous risk assessment process should be followed and documented and should consider:

- Penetration type e.g., ESP cable, gauge cable, chemical injection line, control line.
- Potential leak paths e.g., encapsulation, cable material, hydraulic line, bonding of barrier material.
- Encapsulation material e.g., plastic type, damage during installation, interfaces between materials.
- Degradation e.g., plastic encapsulation shrinkage, metal corrosion, barrier material interface, with consideration of temperature and fluid environment.
- Leak path failure modes, and well specific risk profile, which may include crossflow modelling.
- Alternative isolation material requirements including seal-healing properties.

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3.3.6.3 Bull-heading

Bull-heading of cement into perforations can form a permanent barrier, provided the principle of cap rock restoration still applies.

Considerations for bull-headed decommissioning barriers include:

- Tubing and casing integrity
- Cement slumping
- Contamination
- Channeling
- Small volume/capacities
- Reservoir injection capability
- Losses
- Tubing debris, such as scale and wax deposits
- Ability to verify by tag (e.g. wireline access depth in high angle wells).

3.3.6.4 High Angle and Horizontal Wells (wells > 70°)

In principle, the decommissioning of a horizontal well is no different from a standard well. The only difference is in the means of ensuring a satisfactory isolation, which is in general more difficult to achieve, see figure 18 below.

Additional considerations in these wells include:

- Isolation of zones with flow potential from each other at high angle
- The final vertical thickness of installed barriers
- Wireline access depth for tagging cement.

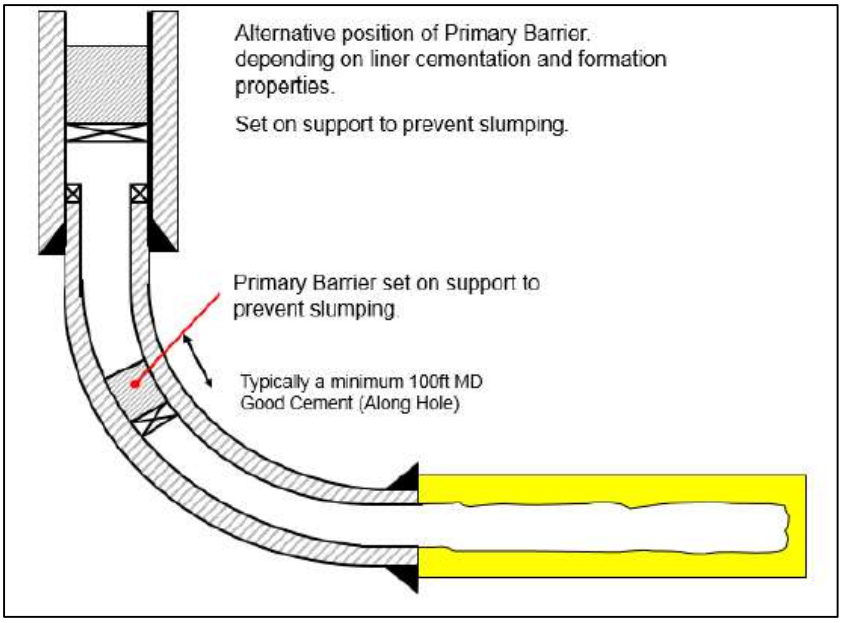

Figure 18: Example isolation of high angle well

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3.4 Verification of a Permanent Barrier

3.4.1 Overview

Any permanent barrier should be verified to ensure the barrier is placed at the required depth and will have the required sealing capability.

Examples of verification methods include:

- Tagging
- Pressure testing
- Inflow testing
- Pumping Records
- Well history
- Modelling
- Lab testing
- Field experience
- Logs
- Sampling

Verification requirements are dependent upon the individual well, job design, barrier material used and placement method.

3.4.2 Wellbore Barrier

The cement barrier should be verified by an appropriate combination of the following:

- The barrier installation should be documented, including records from the cement operation (volumes pumped, returns during cementing, water-wetting pills, etc).
- The strength development of the cement slurry should be confirmed. This is primarily done using pre-job testing with representative component samples cured at anticipated downhole temperature and pressure.
- The position of a barrier should be verified by tagging, calculation or measurement to confirm the depth of the firm cement plug.
- Tagging with drillpipe this is typically 10 to 15 klbs.
- Tagging with wireline, coiled tubing or stinger; the weight will be limited by tools and geometry.
- A pressure test should:
    - be a minimum of 500 psi above the leak off pressure below the barrier (e.g. into perforations or open formation below the casing shoe); but
    - not exceed the casing strength minus wear allowance or damage the primary casing cement, whichever is lower.
- Inflow test should consider the maximum pressure differential to be experienced by the barrier.

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In cased hole, if a pressure tested and tagged mechanical plug or previous cement plug is used as a foundation for the barrier, then:

- Pressure-testing of the cement barrier may not be meaningful.
- Tagging may not be necessary if the cement job goes as planned. However, if a decision is made not to tag a cement plug then the rationale should be documented and risk assessed. This should consider well conditions, plug length and volume, job trends and execution performance, other verification methods and consequence of failure. If circumstances exist that increase the risk (e.g., shortened cement plug, high pressure and temperature, well integrity concerns, method of placement, execution anomalies) then tagging would be advised.

It is acknowledged that alternative materials may be used. The verification method should prove the barrier is adequate to prevent flow of the present fluids at the maximum anticipated pressures in the direction of flow.

3.4.3 Annular Barrier

The annular barrier should be verified by an appropriate combination of:

- Testing (e.g. perforate and test)
- Records from cementing operations (e.g. volumes pumped, returns during cementing, differential pressure, losses, centralization etc.).
- Sufficient annular isolation through the original cement job. If the quantity of annular cement (the estimate of TOC) is to be based on differential pressure or monitored volumes during the original cement job (rather than logs for instance), then a longer cement column may be required to allow for uncertainty. In this case, a 1,000-foot MD column may be considered adequate for the equivalent of two barriers or a combination barrier based on the assumption that sealing has occurred somewhere in the annulus cement. This may be increased or decreased on a well-by-well basis depending on the confidence level of the original cementation (refer to Figure 19).
- Casing pressure history during the life cycle of the well
- Well-integrity reporting
- The leak-off test when the casing shoe was drilled out Field experience.
- Pressure test
- Modelling of well lifecycle loading
- Modelling of cement job
- Logs (e.g. cement bond, temperature, sonic)
- Sampling of annular fluids

Validity of historical data (logs, cementing records etc.) should be considered based on potential isolation degradation, or potential improved sealing properties, over time.

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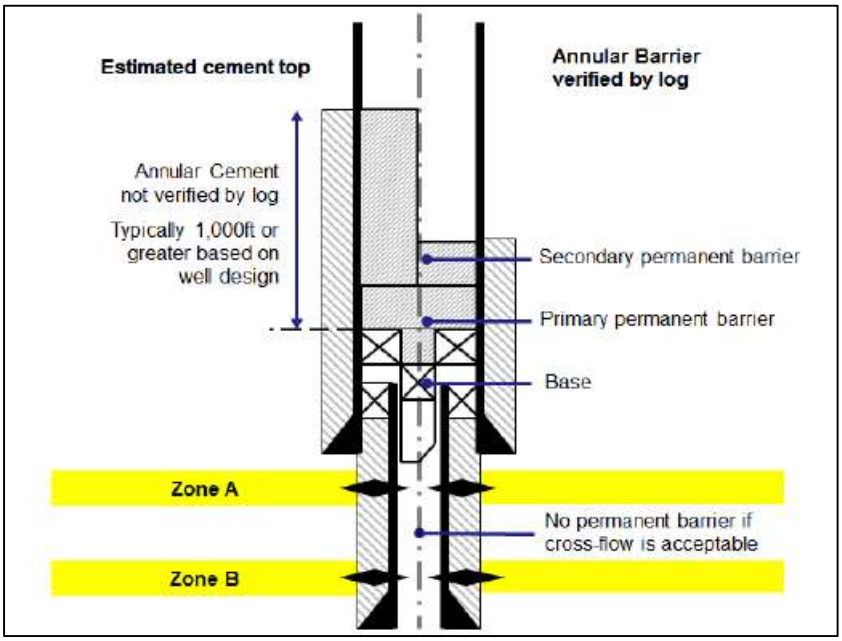

Figure 19: Example cased hole decommissioning schematic

3.4.3.1 Verifying Sealing Formations

In addition to the previous, the verification of a formation seal requires:

- Evidence that the formation has the required fracture strength to withstand the maximum anticipated pressures.
- The length of the resulting seal of the formation against the casing is adequate to prevent flow of the present fluids at the maximum anticipated future pressures, for example differential pressure testing across a suitable length.

Once sufficient field experience is gained, it may be possible to use only one of the above verification techniques (logging or differential testing) when accepting a barrier; such a decision should be documented. Sealing formation verification can potentially be extrapolated to other wells that are geologically similar.

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3.4.3.2 Verifying through-tubing and bull-heading

In addition to the previous, there can be less available accurate methods of determining cement quality and quantity in both tubing and annulus after through tubing or bull-headed barriers are placed. No single verification method should be relied on exclusively. Additional considerations for verification of bull-headed or through-tubing barriers could include:

- Pressure responses during dumping and displacement
- Reservoir injection characteristics before, during and after placement

3.4.3.3 Liner Laps

Cement across a liner lap should not be part of a permanent barrier unless it has been verified. If the cement quality in the liner lap is uncertain, the cement barrier should be placed above and/or below the liner lap.

A liner top packer is not a permanent barrier.

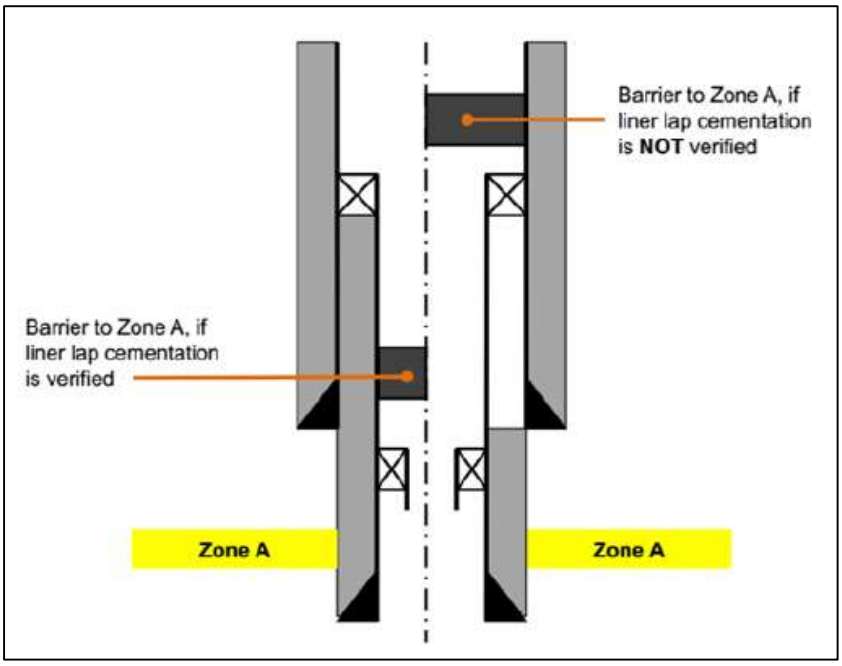

Figure 20: Liner lap cementation

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3.5 Cellars and locations remedial

In the final step to complete the decommissioning of a well onshore, it is recommended to fill up the cellar after the conductor pipe and the casings have been retrieved and removed from the well.

A typical methodology is to back fill to surface with soil material and return the location to its pre-lease state.

Figure 21: Filled cellar - Nziembou in Gabon

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4. Perenco Group expertise in decommissioning

As a specialist in operating mature fields, decommissioning its installations is of interest to Perenco. Such operations encompass many technical, environmental and regulatory challenges. In the past few years Perenco has decided to face those challenges and get ready for the wave of decommissioning projects, some of which have already been executed successfully in the North Sea and in West Africa. Rather than leaving behind such liability to future owners of the installations or delaying the operations, Perenco has decided to adopt a proactive attitude towards decommissioning liabilities and has become one of the most advanced operators in the execution of Decommissioning projects. The group considers this activity as a normal part of the lifecycle of the fields and takes full ownership of it.

4.1 A New industry

Decommissioning an installation is the result of a long and regulated process involving the operator, its partners, the authorities, and the local community. It consists in ensuring that the site will be left as close as possible to its original state with minimal impact on the environment. The main elements of offshore decommissioning projects are the Plug and Abandonment of the wells, the preparation of the installation including its cleanup (hydrocarbon free phase), the removal and transport and the final demolition and recycling. Onshore, the concept is similar with a larger focus on returning the premises to their original state. The large majority of the materials is recycled thanks to the high metal content.

At the crossroad of various oil and gas specialties (well operations, integrity, process, construction and lifting), decommissioning requires a new mix of competencies and a special mindset to successfully engineer and execute the projects. Perenco has recognized this need at an early stage and put in place a dedicated strategy to tackle the decommissioning liabilities across the group.

4.2 Dedicated tools

As a result of a deep thought on the best decommissioning strategy, Perenco has decided to equip itself with a purpose-built decommissioning entity. Its objective is to capitalize on the experience of the team, the construction of dedicated assets and the ability to project this vehicle across all its subsidiaries and all its projects.

In 2018, Petrodec was created in the Netherlands and since then, the company, which is the strong arm of the Perenco group in the field of decommissioning, has executed multiple challenging projects in the North Sea for Perenco.

Petrodec has grown from an idea to a robust and ISO certified decommissioning service contractor fully capable to provide best in class services. Deeply rooted in technical knowledge Perenco prides itself of having given birth to an equally technically and innovatively minded company. Petrodec holds a patent for its skidding technique (safer and

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cost-efficient solution to topside removal) and has performed several very innovative operations.

4.3 Specific challenges and opportunities

As mentioned earlier on, decommissioning operations require specific competencies, mindset and tools. Unlike new projects and green or brown field developments, such operations require heavy intervention on old and aging assets, an interest digging into archives for data mining and the ability to connect the dots while thinking out of the box to solve problems which had never been thought of.

The decommissioning teams at Perenco are facing multiple issues ranging from Well integrity to heavily corroded structures, NORM contaminated wellbore equipment or even collapsed structure. Yet they are as eager to progress and deliver best possible solutions as they can be when planning for the new developments.

Among the possibilities of outcomes for a decommissioning project, it is important to mention the re-use option. As an alternative to the removal and the recycling, Perenco always strives to encourage the re-use of its installation when possible. The Welland platform is an example of a successful re-use of a topside which left the UK waters to continue serving a different purpose in Cameroon. Currently, several studies are under way in the Southern North Sea to evaluate the possibility of leaving in place some installations for birds nesting purpose.

Last, in some regions, and Perenco actively promotes such solutions, rig to reef strategies are used to minimize the disturbance of the decommissioning activities on the environment. Those aim at neutralizing the installations, removing any harmful substances and leaving in place the steel to provide a natural habitat for fishes and other marine species.

4.4 Our achievements to date

So far Perenco has executed 11 Decommissioning projects: Welland (2010-2016), Thames (2013-2018), Tyne and Guinevere (2019), Pickerill A&B (2020), Galahad (2021), Bessemer (2021), Amethyst A1D, B1D, C1D and A2D (2021-2023) and is continuing with a full stream of operations in the North Sea (together with Petrodec).

The decommissioning activity has also started in the Republic of Congo waters where removal of three platforms has been completed early 2022, as well as in Colombia where 10 onshore wells have been abandoned in addition to the Balay field. This totalizes more than 24,000 tons of steel removed and almost 100 wells abandoned (including 6 subsea wells).

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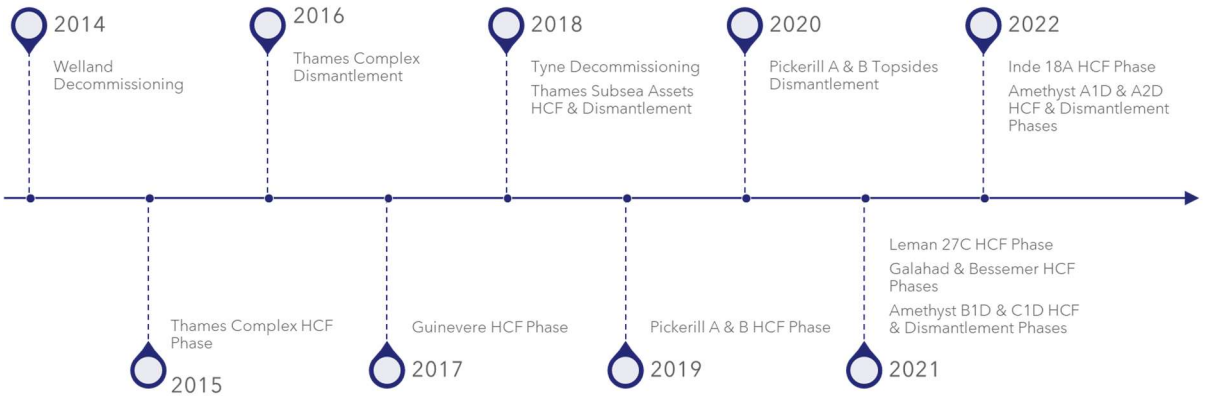

Figure 22: Perenco UK Decommissioning activities timeline

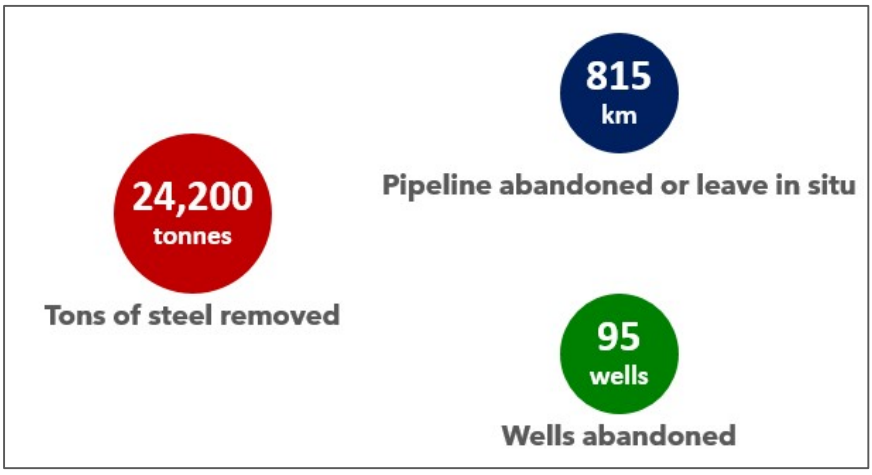

Figure 23: Decommissioning metrics of the Perenco Group

The work is there and the commitment to execute it has never been so strong. It's a long-term vision, on par with Perenco long term production strategy, that is now being rolled out wherever the need arises. Starting from the UK sector of the North Sea, reaching now the warmer waters of the Gulf of Guinea and to be exported in other regions when adequate.

This dedication and know how, which is found in the subsidiaries as well as within Petrodec is one of the keys of the success of such operations. Being able to address and control its decommissioning liability has now become an asset for the Perenco group which can capitalize on it to further develop and expand.

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4.5 England – Amethyst C1D platform removal

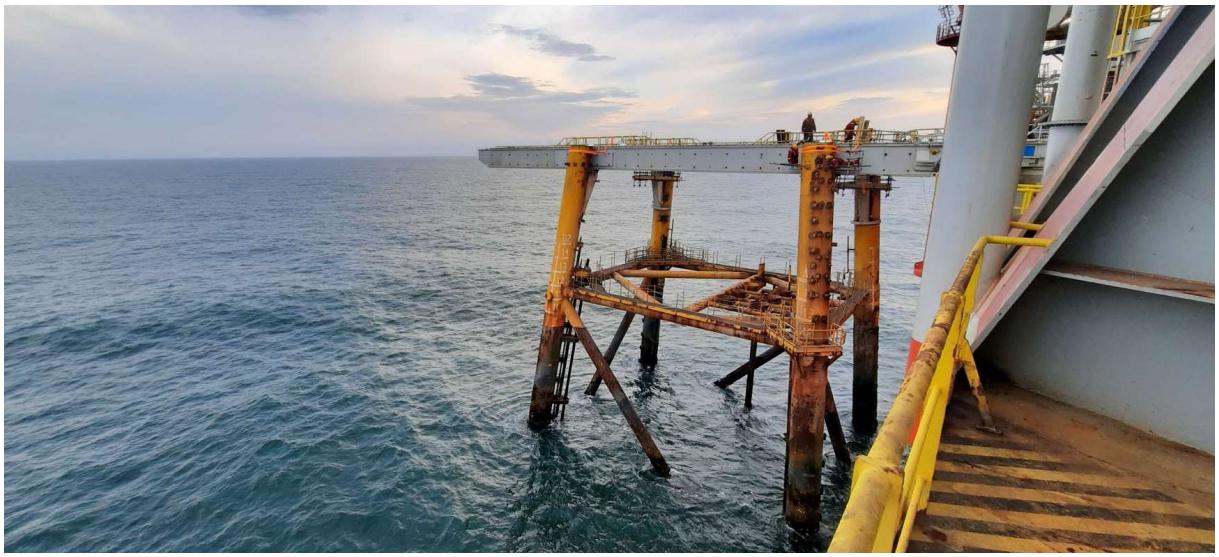

Figure 24: Amethyst C1D platform after topside removal

Figure 25: Amethyst C1D topside loaded onboard ERDA jack up barge

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Figure 26: Amethyst C1D topside offloaded onshore for dismantlement

4.6 Congo – Emeraude decommissioning project

This first project conducted in West Africa, Congo consisted on the removal of 3 tripods on the Emeraude field. Also were included the plugging and abandonment of 2 wells.

Figure 27: Decommissioning barge installed on location for tripod removal

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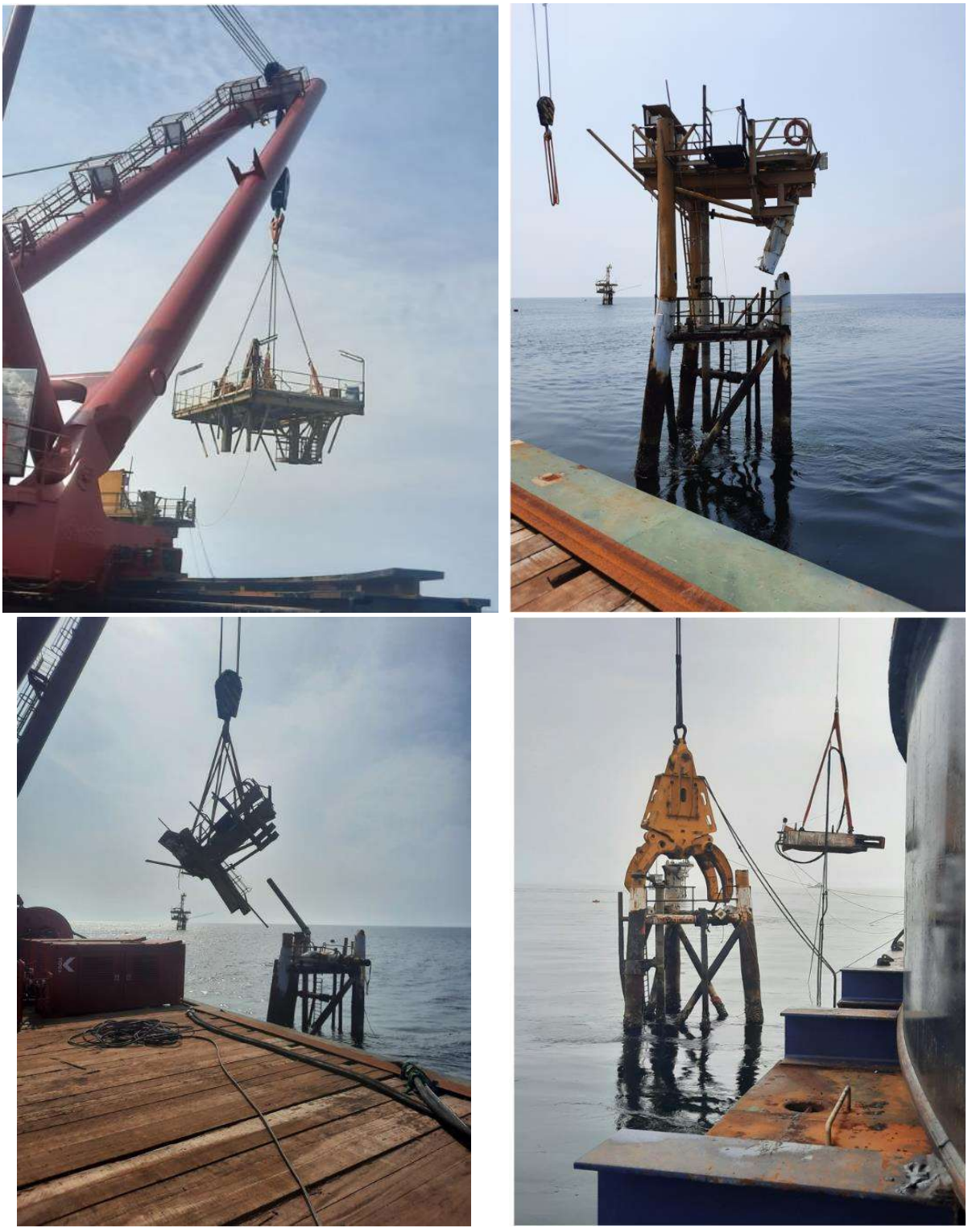

Figure 28: Cut and lift of topside and jacket

A specificity of this project was the conversion of the bottom part of the jackets into artificial reefs. The Congolese authorities had approved the artificial reef conversion to create new habitat for the biodiversity in the area.

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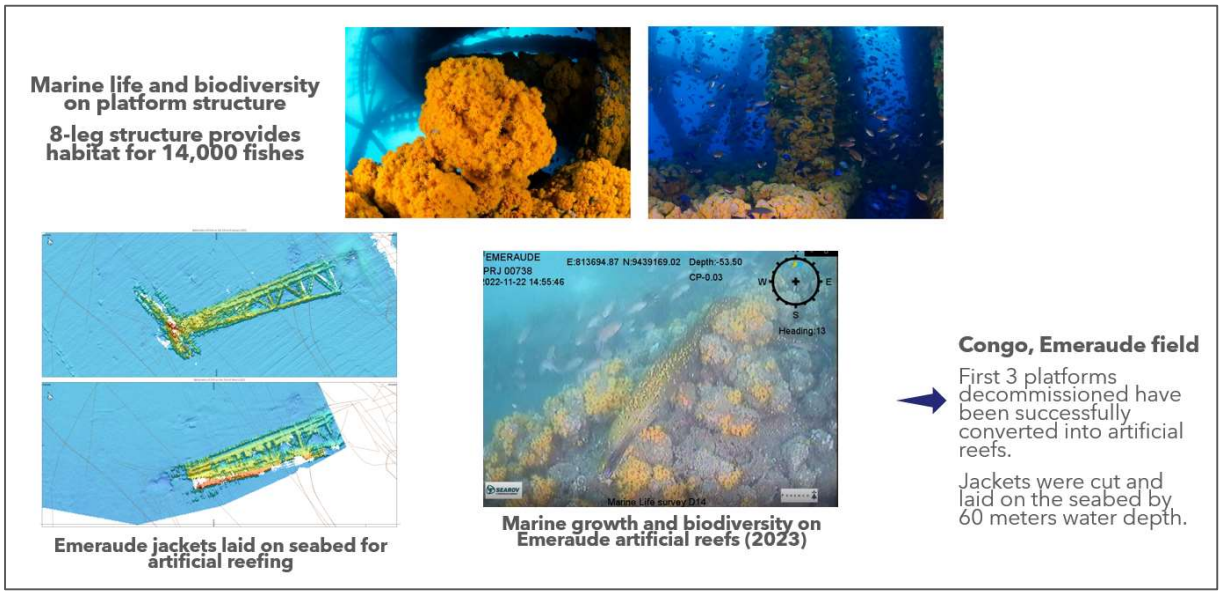

Figure 29: Artificial reefing on Emeraude field, Congo

4.7 Onshore wells abandonment experience

The Perenco Group has completed several well decommissioning onshore over the last years (Gabon, Colombia).

Below are presented various completion schematic diagrams after the finalization of the decommissioning. It shows a great diversity of mechanical status.

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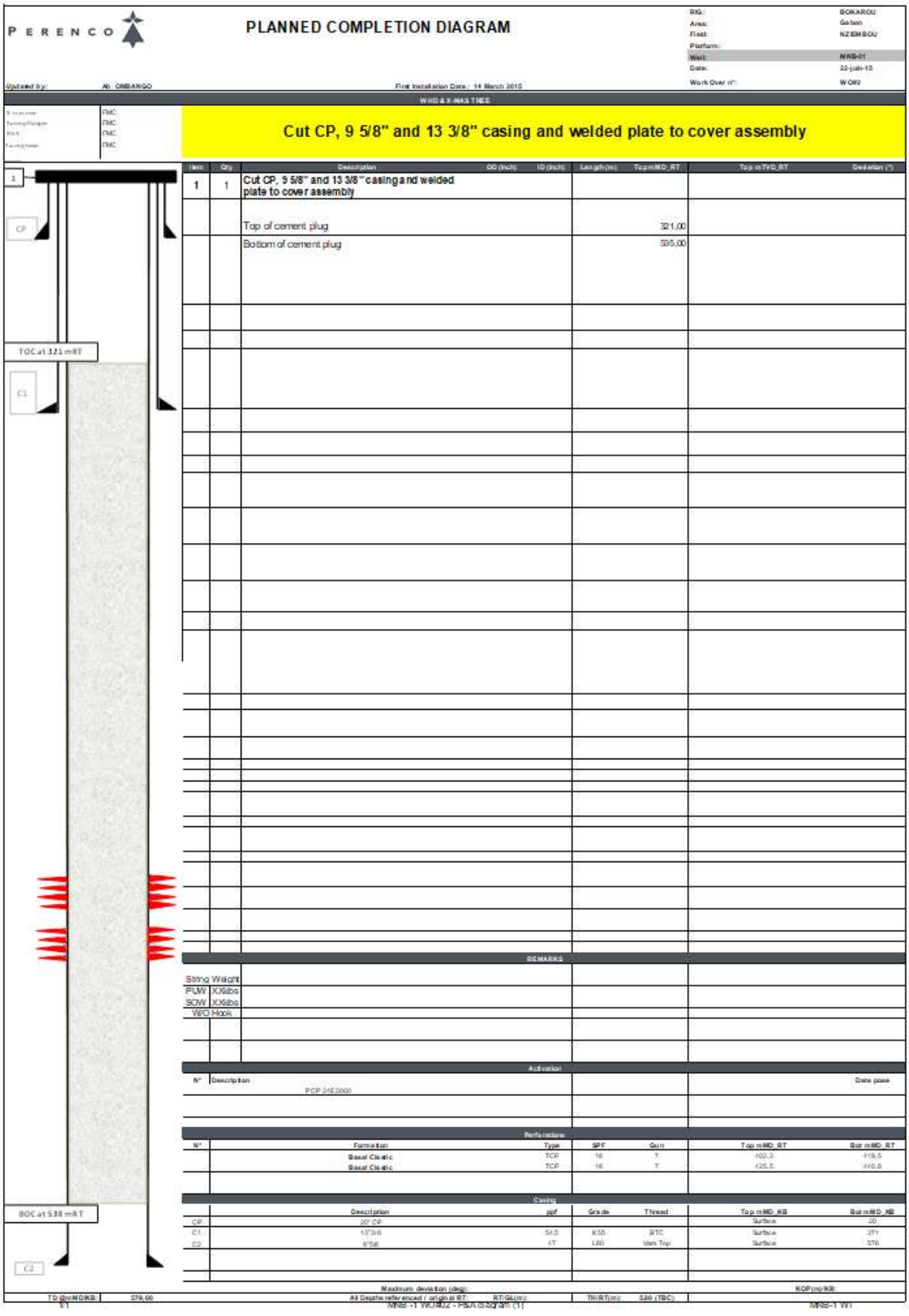

Figure 30: Gabon onshore Well P&A completion

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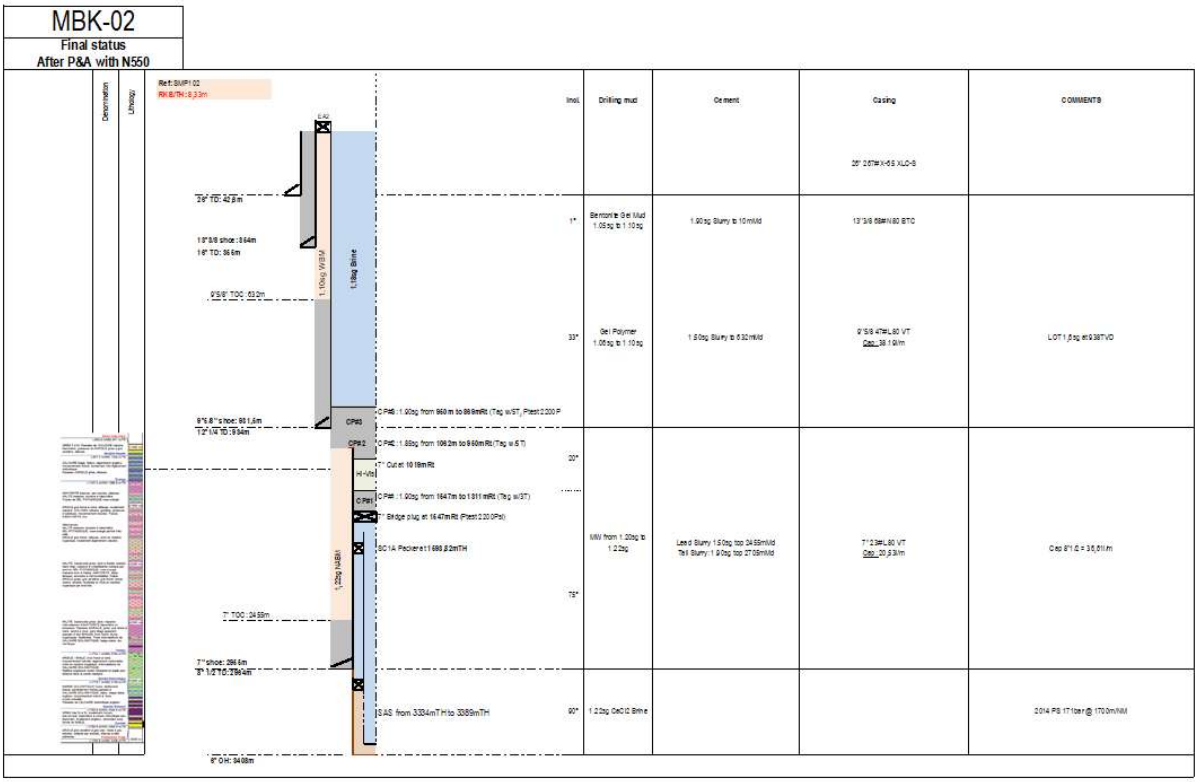

Figure 31: Gabon onshore Well P&A completion (2)

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